AN   1993:43876 HCAPLUS
DN   118:43876
OREF 118:7835a,7838a
TI   Brazing filler for copper and its alloys
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SO   U.S.S.R.
     From: Izobreteniya 1992, (3), 60.
     CODEN: URXXAF
DT   Patent
LA   Russian
FAN.CNT 1

	PATENT NO.	KIND	DATE	APPLICATION NO.	DATE
PI	SU 1706816	A1	19920123	SU 1990-4799962	19900307 <--
PRAI	SU 1990-4799962		19900307		

AB   Shrinkage porosity in the joints is decreased, and the strength is increased when the braze alloy contains In 0.5-1.5 and Si 1.0-4.5% in addition to Ni 8-15, Sn 5-12, P 5-10%, and Cu as the balance.

PTO 08-7317 CC=SU DATE=19920123 KIND=A1
PN=1706816

SOLDER FOR SOLDERING COPPER AND ALLOYS THEREOF
[PRIPOY DLYA PAYKI MEDI I YEYO SPLAVOV]

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UNITED STATES PATENT AND TRADEMARK OFFICE
Washington, D.C. August 2008

Translated by: FLS, Inc.

PUBLICATION COUNTRY	(19):	SU
DOCUMENT NUMBER	(11):	1706816
DOCUMENT KIND	(12):	A1
PUBLICATION DATE	(46):	19920123
APPLICATION NUMBER	(21):	4799962/27
APPLICATION DATE	(22):	19900307
INTERNATIONAL CLASSIFICATION	(51):	B23K 35/30
PRIORITY COUNTRY	(33):	NA
PRIORITY NUMBER	(31):	NA
PRIORITY DATE	(32):	NA
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DESIGNATED CONTRACTING STATES	(84):	NA
TITLE	(54):	ALLOY FOR SOLDERING COPPER AND ALLOYS THEREOF
FOREIGN TITLE	[54A]:	PRIPOY DLYA PAYKI MEDI I YEYO SPLAVOV

Description /1*

The invention concerns machine construction, in particular for soldering metal articles made of copper and alloys thereof, German silver, nickel, molybdenum, and also ceramics and metal ceramics, using homogenous plastic strip or powdered copper-based solders as the solder.

These solders are intended to provide strength and corrosion resistance of the solder joint, a lower soldering temperature, and self-fluxing. In addition, one of the basic requirements is absence of porosity in the solder seam, which is necessary for soldering certain important articles, for example parts intended for connecting radio measuring apparatus. The presence of porosity in solder joints leads to a reduction of the annual production output.

Silver-containing solders of the PSr45 and PSr72 type, known from All-Union State Standard 19738-74 and having 39-72% by weight of silver in their composition, are known. The solders are used for soldering parts made of copper and its alloys, in particular brass parts. They have high strength and corrosion resistance in the joint, a relatively low soldering temperature, the metals soften well and flow into gaps. They provide the following properties, shown in Table 1.

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*Numbers in the margin indicate pagination in the foreign text.

The scarcity and high cost of silver, the expensive technology of producing solders, and also the porosity of the area of the solder seam are disadvantages of these solders.

The solder PMFS6-0.15 for soldering parts made of copper and alloys thereof is known.

The solders have the composition and properties shown in Table 2.

Solder is characterized by the complex technology of producing /2 it and using it for soldering. Porosity also is detected in a joint made with the above-mentioned solder, although the amount of porosity is 10% lower than in the case of using silver solders. In addition, the residues of the flux used in soldering cause corrosion of the seam, reducing the strength characteristics.

Copper-based alloys are known.

The solder has the composition given in Table 3.

The solder of the most common composition contains, in % by weight:

nickel	9.91
tin	4.00
phosphorous	7.84
copper	78.25

The basic characteristics of the solder are the following:

temperature - solidus, °C	610
temperature - liquidus, °C	730-780

tensile strength, MPa	208
seam porosity, %	10-15

The solder has satisfactory temperature and strength characteristics, is self-fluxing, and may be used instead of silver-containing solders for soldering copper and alloys thereof.

A disadvantage of this solder is the porosity of the solder seam due to the long solid-liquid hardening time at the time of making a joint. The pore concentration in fillet sections of the seam is especially high. In this case the porosity of the joint, sealing, and vacuum density are decreased, which reduces the area of its application.

The purpose of the invention is to reduce the shrinkage porosity of the soldered seam and to strengthen the solder joint.

In order to achieve the indicated goal in a solder containing copper, nickel, tin, and phosphorous, silicon and indium are additionally introduced with the following ratio of components, in % by weight:

nickel	8.0-15.0
tin	5.0-12.0
phosphorous	5.0-10.0
indium	0.5-1.5
silicon	1.0-4.5
copper	remainder

the total indium and silicon content being 1.5-5.5 % by weight.

Reduction of the shrinkage porosity and strengthening of the solder joint are achieved by alloying the solder with silicon and indium within the indicated limits.

The porosity of the solder seam was studied on microsections, the concentration of shrinkage pores was evaluated by radiographic monitoring in flat and fillet sections of the seam.

The solder alloy is melted in an argon atmosphere in an induction furnace. The components, namely copper, nickel, tin, silicon, and copper phosphide are put into a crucible. The crucible is put into a furnace, heated to 1080-1090°C until complete melting of all components, the temperature of the melt is gradually reduced to 750-800°C, and the indium is introduced. After complete dissolution of the indium the melt is cooled.

The proposed solder is prepared in the form of a film, or strip and powder. A strip 0.02-0.06 mm thick is obtained by rapid cooling of the melt by means of putting it onto a cooled metal disk, revolving at a speed of 20-40 m/s.

Powder is obtained by centrifugal dispersion of the melt on a disk. Both processes provide for the presence of an amorphous or microcrystalline phase in the structure.

A solder of a known alloy is produced in parallel. The solder is produced in the form of a strip 10-40 mm wide and 0.02-0.06 mm thick.

Solder samples are prepared in accordance with All -Union State Standard 23047-78 for expansion tests. Sheet copper is used as the

basic material and L63, LS59 brass 1.5 mm thick is used as the welding strip. The samples are soldered overlapped, the amount of overlapping being 3 mm. Before soldering the samples are degreased with acetone and washed with alcohol, and are subjected to chemical pickling. Boric acid or F209 flux are used as the flux. The solder is placed so that it completely covers the entire area of overlapping. Then the samples are fastened and soldered with a torch with a reducing flame, after which they are cooled to room temperature and the flux residues are removed mechanically.

The characteristics of joints soldered with strip solders of known and proposed components at the lower, middle, and upper limits, and also exceeding the lower and upper limits are given in the table.

The results of the tests of the joints soldered with the proposed solder demonstrated their advantage in comparison with the known solder. The best combinations of solder properties are obtained in the case of the addition of silicon in an amount of 1.0-4.5, indium 0.5-1.5% by weight, the total silicon and indium content being in an amount of 1.5-5.5 % by weight. In this case the soldering temperature is lowered, the strength of the joint is increased, /3
and a practically complete absence of shrinkage porosity due to the shortening of the solid-liquid state period at the time of hardening is observed. In addition, the solders do not corrode during long-term storage.

When silicon and indium are introduced in amounts below the lower limit into the composition of the alloy, the hardening time increases and formation of shrinkage porosity becomes possible; in the case of introducing the indicated additives above the overall upper limit the solder seam becomes brittle.

The advantage of the solder is that it can be used without complex fluxes. Powdered solder of this composition does not need additional preparation.

The technical-economic advantages of using the proposed solder consist in the possibility of using the former for producing a reliable inexpensive solder joint.

The cost of a joint soldered with silver solder is 15 rubles, the cost of a joint soldered with the proposed solder is 3 rubles. The economic effect per 1 thousand parts

$E = (15-3) \cdot 10^3 = 12,000$ rubles.

The technical advantages of using the solder are that the solder joint has great strength, and the solder seam does not have pores, which expands the area of its application in technology.

Formulation of the Invention

A solder for soldering copper and alloys thereof, containing nickel, tin, and phosphorous, wherein, in order to reduce the shrinkage porosity of the solder seam and strengthen the solder joint, the solder additionally contains silicon and indium with the following ratio of components, in % by weight:

nickel	8-15
tin	5-12
phosphorous	5-10
indium	0.5-1.5
silicon	1.0-4.5
copper	remainder

Table 1

solder brand	content in composition, % by weight			temperature, °C		tensile strength, MPa	porosity, %
	Ag	Cu	Zn [sic]		liquid solder		
PSr45 PSr72	44.5-45.0 71.5-72.5	29.5-30.4 remainder	remainder -	610 779	680-780 808-850	144 185	15 20

Table 2

solder brand	content in composition, % by weight				temperature, °C		tensile strength, MPa	porosity, %
	Cu	Ag	P	Si	liquid solder			
PMFS6-0.15	remainder	3	5-6	0.15	710	750-780	140-149	5-10

Table 3

Ni	Sn	P	Cu
6.5-48.24	4.0-18.5	4.8-7.8	remainder

Table 4

Припой	Содержание компонентов, мас. %							Температура, °C		Прочность на растяжение паяного шва, МПа	Усадочная пористость на участке паяного шва	
	Ni	Sn	P	Cu	Si	In	Si+In	солидус	ликвидус		плоских	тавровых
1 Известный	9.93	4.0	7.84	78.25	-	-	-	610	680	208	10	15
2 Предлагаемый	8.0	5.01	5.00	80.49	1.0	0.5	1.5	595	677	221.4	-	-
3	8.0	5.02	5.00	76.70	3.2	2.08	5.28	593	673	223.3	-	-
4	8.0	5.00	5.02	76.48	4.0	1.5	5.5	592	680	222.3	-	-
5	8.0	5.00	5.00	76.5	4.5	1.0	5.5	593	673	215	-	-
6	12.0	8.00	7.5	71.0	1.0	0.5	1.5	592	676	224	-	-
7	12.6	8.00	7.5	68.64	2.21	1.05	3.26	591	672	223.3	-	-
8	12.0	8.5	7.5	66.5	4.5	1.0	5.5	590	678	218.5	-	-
9	12.0	8.1	7.5	66.9	4.0	1.5	5.5	589	671	212	-	-
10	15.0	12.0	10.0	61.5	1.0	0.5	1.5	600	686	211	-	-
11	15.0	12.0	10.0	59.79	2.21	1.0	3.21	605	675	210	-	-
12	15.0	12.0	10.0	57.5	4.5	1.0	5.5	602	670	218	-	-
13	15.0	12.0	10.0	57.5	4.0	1.5	5.5	605	674	209	-	-
14 Выходящий за пределы по составу	8.0	5.0	5.0	76.41	4.09	1.5	5.59	623	698	185	4	7
15	8.0	5.01	5.0	76.39	4.5	1.1	5.6	629	689	172	3	6
16	9.0	8.5	7.5	73.59	0.05	1.36	1.41	611	698	202	7	17
17	10.0	8.0	7.5	68.50	4.5	1.5	6.0	598	679	174	8	13
18	7.8	4.5	4.5	81.86	0.94	0.4	1.34	683	750	183	10	14
19	7.8	4.7	4.5	79.80	2.1	1.1	3.2	671	711	110	8	9
20	15.5	12.7	11.0	57.60	2.2	1.0	3.2	631	697	183	7	11
21	15.5	12.5	10.5	55.27	4.5	1.53	5.73	639	693	147	16	23

Remark: Soldering tests were performed on L63 samples.

Key:

solder	component content % by weight							temperature, °C		tensile strength of seam, MPa	shrinkage porosity of solder seam	
								solidus	liquidus		flat	fillet
1 known												
2 proposed												
14 composition exceeding limits												